



# AN OVERVIEW OF THE SCIENTIFIC RESULTS AND ARCHITECTURE OF THE TWO MODULES OF THE CHANDRAYAAN-3 MISSION

Saksham Uboweja

Research Scholars Program, Harvard Student Agencies, In collaboration with Learn with Leaders

## ABSTRACT

The purpose of this study is to explore the two modules that comprise the Chandrayaan-3 Mission by the Indian Space Research Organisation (ISRO). The mission contains a Propulsion Module (PM) and a Lander Module (LM). The Propulsion Module contains the Spectro-Polarimetry Habitable Planetary Earth (SHAPE) payload. The Vikram Lander contains Chandra's Surface Thermo-physical Experiment (ChaSTE), Radio Anatomy of Moon Bound Hypersensitive Ionosphere and Atmosphere - Langmuir Probe (RAMBHA-LP), the Instrument for Lunar Seismic Activity (ILSA) and a passive Laser Retroreflector Array (LRA) from NASA. The Pragyan Rover contains the LASER Induced Breakdown Spectroscope (LIBS) and the Alpha Particle X-ray Spectrometer (APXS). This paper aims to give an overview of the propulsion module, the lander module, and the scientific instruments (ChaSTE, RAMBHA-LP, ILSA, APXS and LIBS) and their scientific results.

**KEYWORDS:** Propulsion Module, Lander Module, SHAPE, ILSA, RAMBHA, ChaSTE, LRA, LIBS, APXS.

## INTRODUCTION

This paper aims to provide an overview of the scientific results and the architecture of the Two Modules of the Chandrayaan-3 Mission. The Indian Space Research Organisation's third space mission to the moon was launched on July 14, 2023, and landed on the Lunar South Pole on August 23, 2023. With its successful landing, India became the first country to soft-land on the south pole of the moon [1]. There is no doubt that space missions to the moon are vital to our understanding of the moon for any future space missions. Now, the successful landing of the Chandrayaan-3 on the Moon begs the question: What is the architecture of the Chandrayaan-3? What are the findings of the scientific instruments on Chandrayaan-3? This paper aims to answer these questions.

## Mission Objectives

The Mission Objectives of Chandrayaan-3 are [1]:

1. To demonstrate a safe and soft landing on the Lunar Surface.
2. To demonstrate rover roving on the lunar terrain.
3. To conduct in-situ scientific experiments.

## Components of the Mission

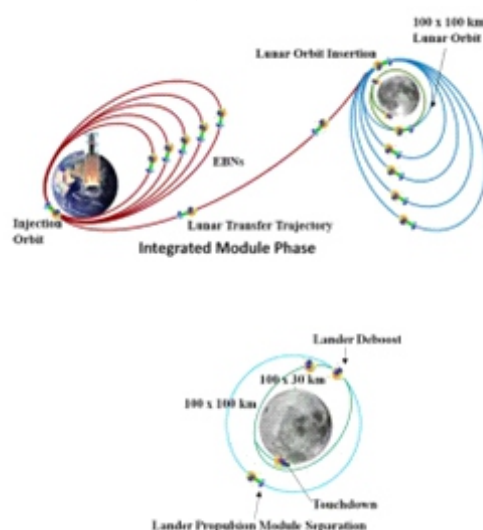
The Chandrayaan-3 Mission has a two-module configuration: an indigenous Propulsion Module that carries the lander from launch injection to the lunar orbit, and a Lander Module, that accommodates the rover. The Propulsion Module has a mass of 2148 kg, and the Lander Module has a total mass of 1752 kg (which includes a rover of 26kg mass). This brings the total mass to 3900 kg [1][2].

## Mission Sequence

Earth Centric Phase (Phase-1)	<ul style="list-style-type: none"> <li>• Pre-launch Phase]</li> <li>• Launch and Ascent Phase</li> <li>• Earth-bound Manoeuvre Phase</li> </ul>
Lunar Transfer Phase (Phase-2)	Transfer Trajectory Phase

### Moon Centric Phase

- Lunar Orbit Insertion Phase (LOI) - (Phase -3)
- Moon-bound Manoeuvre Phase (Phase -4)
- PM and Lunar Module Separation (Phase -5)
- De-boost Phase (Phase -6)
- Pre-landing Phase (Phase -7)
- Landing Phase (Phase -8)
- Normal Phase for Lander and Rover (Phase -9)
- Moon Centric Normal Orbit Phase (100 km circular orbit) - For Propulsion Module (Phase -10) [2]



**Fig. 1: Chandrayaan-3 – Mission Profile Source: ISRO (2023)**

### Propulsion Module

The primary function of the Propulsion Module (PM) is to carry the lander module from the launch vehicle injection until lander separation, or until a 100-kilometer lunar orbit. The PM also carries a scientific payload: Spectro-Polarimetry Habitable Planetary Earth (SHAPE). The PM has a power generation of 738W. The PM communicates with the Indian Deep Space Network (IDSN) [1][2].

Other information about the PM is in the table given below [2]:

Parameter	Specifications
Structure	Modified version of I-3 K
Attitude Sensors	CASS, IRAP, Micro star sensor
Propulsion System	Bi-Propellant Propulsion System (MMH + MON3)

### Vikram Lander

The Vikram Lander has a mission life of 1 lunar day and a mass of approximately 1750 kg, including the 26-kg Rover. It has a power generation of 738 W (Winter Solstice) and consists of three scientific payloads: Radio Anatomy of Moon Bound Hypersensitive Ionosphere and Atmosphere—Langmuir Probe (RAMBHA-LP), Chandra's Surface Thermo-physical Experiment (ChaSTE), and Instrument for Lunar Seismic Activity (ILSA).

Other information about the Lander is in the table given below:

Parameter	Specifications
Dimensions (mm)	2000 x 2000 x 1160
Communication	IDSN, Chandrayaan-2 Orbiter, Rover

The landing site's coordinates are: 69.367621 S, 32.348126 E. To achieve the mission objectives, the lander also has the following technologies:

1. Altimeters: Laser & RF based Altimeters
2. Velocimeters: Laser Doppler Velocimeter & Lander Horizontal Velocity Camera
3. Inertial Measurement: Laser Gyro-based Inertial referencing and Accelerometer package
4. Propulsion System: 800N Throttleable Liquid Engines, 58N attitude thrusters & Throttleable Engine Control Electronics
5. Navigation, Guidance & Control (NGC): Powered Descent Trajectory design and associated software elements
6. Hazard Detection and Avoidance: Lander Hazard Detection & Avoidance Camera and Processing Algorithm
7. Landing Leg Mechanism.

To demonstrate the above-mentioned advanced technologies in

Earth conditions, several Lander special tests have been planned and carried out successfully, namely:

1. Integrated Cold Test - For the demonstration of the Integrated Sensors & Navigation performance test using a helicopter as a test platform
2. Integrated Hot test – For the demonstration of closed-loop performance test with sensors, actuators and NGC using a Tower crane as a test platform
3. Lander Leg mechanism performance test on a lunar simulant test bed simulating different touch-down conditions [1][2].

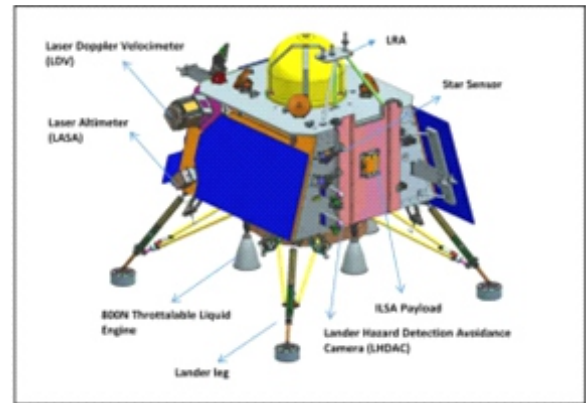


Fig. 2: Chandrayaan-3 Lander  
Source: ISRO (2023)

### Pragyan Rover

The Pragyan Rover, just like the lander, also has a mission life of 1 lunar day. It has a mass of 26 kg and a power generation of 50 W. It has two scientific payloads: a LASER Induced Breakdown Spectroscope (LIBS) and an Alpha Particle X-ray Spectrometer (APXS). Its dimensions (mm) are 917 x 750 x 397, and it communicates with the Lander [2].

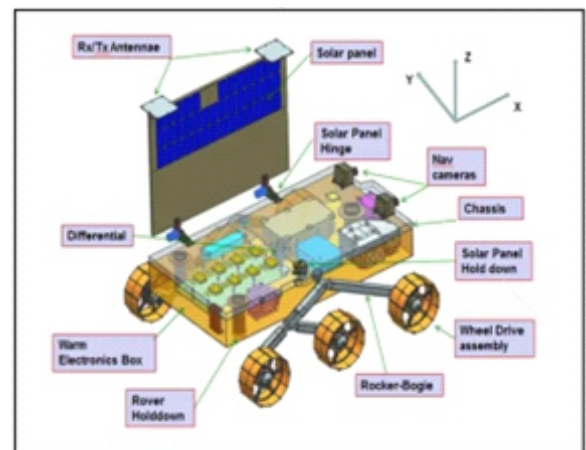
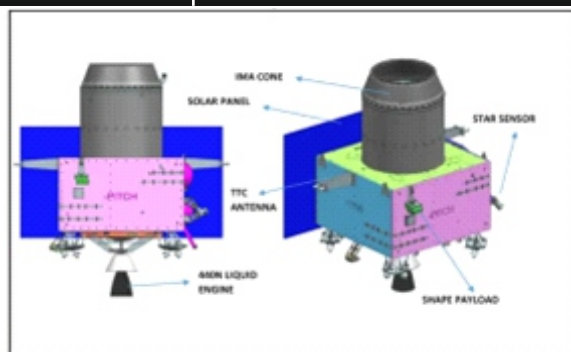


Fig. 3: Chandrayaan-3 Rover  
Source: ISRO (2023)

### Scientific Payload Onboard Chandrayaan-3 and their Results

**Spectro-Polarimetry Habitable Planetary Earth (SHAPE):** It is the scientific payload that is being carried by the Propulsion Module. Its role is to study the spectral and polarimetric measurements of Earth from the lunar orbit, in the near-infrared (NIR) wavelength range (1-1.7  $\mu\text{m}$ ) [2].



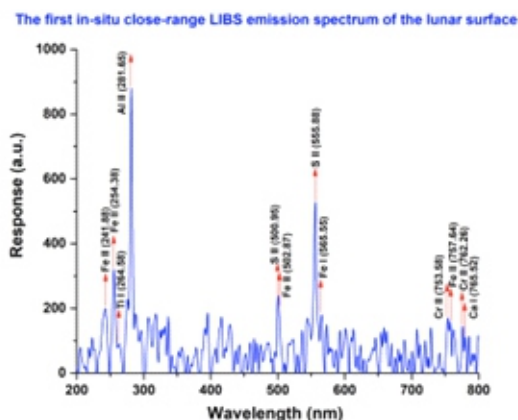
**Fig. 4: Chandrayaan-3 Propulsion Module**  
Source: ISRO (2023)

## LASER Induced Breakdown Spectroscopy (LIBS)

LIBS is one of the two scientific payloads present on the Rover in Chandrayaan-3. The LIBS method can provide the elemental composition of samples, regardless of their physical state [3]. "This technique analyses material composition by exposing it to intense laser pulses. A high-energy laser pulse is focused onto the surface of a material, such as a rock or soil. The laser pulse generates an extremely hot and localised plasma. The collected plasma light is spectrally resolved and detected by detectors such as Charge Coupled Devices (CCDs). "Since each element emits a characteristic set of wavelengths of light when it's in a plasma state, the elemental composition of the material is determined" [4]. The objectives of LIBS are: to identify and derive the abundance of elements that are commonly found in lunar rock-forming minerals, i.e., O, Na, Mg, Al, Si, K, Ca, Fe, Cr, Mn, Ti, etc. and to detect volatile and trace elements (H, C, N, S, and P) in the vicinity of the landing site. These observations could enable the investigation of hydrates and organic content in the sampling area by analysing H, C, N, and O emission line characteristics. More information about the LIBS instrument is given in the table below [3]:

Parameter	Specifications
Weight	1.2 kg
Power consumption	< 5W
Footprint	180mm x 150mm x 80 mm
Resolution	≤1 nm
Spectral range	220-800 nm
Operating Temperature (°C)	-20 to +55

The in-situ measurements carried out by the LIBS have shown the presence of Aluminium (Al), Sulphur (S), Calcium (Ca), Iron (Fe), Chromium (Cr), and Titanium (Ti) on the moon. They have also helped confirm the presence of Sulphur (S) unambiguously [4].



**Fig. 5: The first in-situ close-range LIBS emission spectrum of the lunar surface Source: ISRO (2023)**

### Alpha Particle X-ray Spectrometer (APXS)

The APXS is also a scientific payload present on the Rover of the mission. The APXS instrument consists of two packages: the APXS sensor head and the APXS backend electronics. The APXS sensor head will be mounted on a robotic arm. On command, the robotic arm brings the sensor head close to the lunar surface and brings it back up [5]. The primary scientific objective of APXS is to determine the elemental composition of the lunar surface in the regions surrounding the landing site by employing the technique of X-ray fluorescence spectroscopy using an in-situ excitation source. APXS uses 244 cm radioactive sources emitting both alpha particles having energy of 5.8 MeV and X-rays having energy of 14.3 and 18.3 keV, which excites the elemental characteristic X-rays by the processes of particle induced X-Ray emission (PIXE) and X-ray fluorescence (XRF). The characteristic X-rays are detected by the Silicon Drift Detector, which provides high resolution and efficiency in the 1-25 keV energy range. This thus allows the APXS to detect the composition of elements like Sodium (Na), Magnesium (Mg), Aluminium (Al), Silicon (Si), Calcium (Ca), Titanium (Ti) Iron (Fe), Strontium (Sr), Yttrium (Y) and Zirconium (Zr). More information about the APXS instrument is in the table below [6]:

Parameter	Specifications
Energy range	1-25 keV
Detector	Silicon Drift Detector (SDD)
Resolution	~135 eV at 5.9 keV
Source	244Cm alpha source

The APXS observations and measurements have discovered the presence of minor elements like Sulphur, along with other expected elements like Aluminium (Al), Silicon (Si), Calcium (Ca), Iron (Fe) [7].

## Chandra's Surface Thermo-physical Experiment (ChaSTE)

The ChaSTE payload is present onboard the mission's lander. Its temperature probe is equipped with a controlled penetration mechanism, which can help it penetrate through the lunar regolith to a depth of  $\sim 10$  cm [8]. The principle objectives of ChaSTE are: to obtain a temperature profile and thermal conductivity within the top 10 cm of the lunar surface at the landing site, understand the thermophysical properties of the lunar surface, and constrain the equilibrium boundary between the internal and external heat fluxes [9]. ChaSTE operates in two modes: Passive Mode Operation: continuous in-situ measurements of temperature at different depths are carried out, and active mode operation: temperature variations in a set period and the regolith's thermal conductivity under contact are estimated [10]. The graph shown below presents the first-ever temperature variations of the surface/near-surface at various depths, as recorded during the probe's penetration, for the lunar south pole [8].



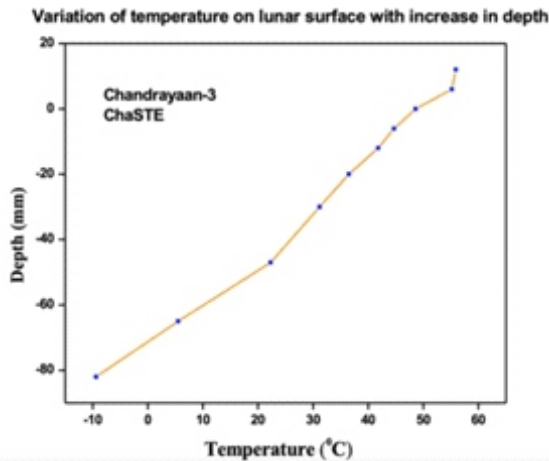


Fig. 6: The variation of temperature on the lunar surface with an increase in depth Source: ISRO (2023)

### Radio Anatomy of Moon Bound Hypersensitive Ionosphere and Atmosphere - Langmuir Probe (RAMBHA-LP)

The RAMBHA-LP payload is present onboard the mission's lander. The RAMBHA-LP payload consists of the mechanical system and the onboard electronics. The mechanical system consists of a spherical conducting Ti alloy probe attached to a non-conducting boom of 1 m (the Langmuir Probe is a 5 cm metallic spherical probe mounted on a 1-meter boom attached to the Chandrayaan-3 Lander's upper deck), a torsion spring-based deployment mechanism, and a hold and release system [11][12]. The onboard electronics system named RAMBHA's primary function is to control sensor voltage, data acquisition, and the spacecraft interface for telecommand (TC), telemetry (TM), and baseband data handling (BDH). The payload is to obtain in-situ measurements of the lunar near-surface plasma at an altitude of ~2 m. information about RAMBHA-LP is in the table given below [11]:

Parameters	Specifications
Minimum sweep voltage (V)	-12
Maximum sweep voltage (V)	+12
Data sampling rate (ms)	1
Bias voltage steps (V)	0.1
Step dwell time (ms)	60

The primary scientific objectives are: (i) to make in situ measurements of the ambient electron density/temperature near the lunar surface and (ii) to study the temporal evolution of the lunar plasma density for the first time near the surface under varying solar conditions [11]. The results of RAMBHA's readings are given below.

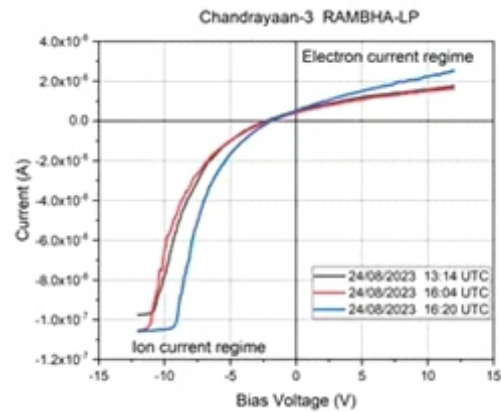


Fig. 7: Scientific readings obtained by the RAMBHA-LP Payload Source: ISRO (2023)

### Instrument for Lunar Seismic Activity (ILSA)

The Instrument for Lunar Seismic Activity (ILSA) is onboard the Chandrayaan-3 lander. This scientific instrument is the first instance of a Micro Electro Mechanical Systems (MEMS) technology-based instrument on the moon [13]. ILSA is also capable of detecting minute ground displacement, velocity, or acceleration caused by lunar quakes [14]. The instrument has three axes of high sensitivity accelerometers realised using the silicon micromachining technology called micro-electromechanical systems (MEMS) [13]. The primary objectives of the ILSA scientific instrument are to measure seismicity around the landing site and outline the structure of the lunar crust, the mantle [1]. High-sensitivity silicon micro-machined accelerometer measures ground acceleration due to lunar quakes [13]. Its dynamic range is  $\pm 0.5$  g, which is met by using two sensors—a coarse-range sensor and a fine-range sensor [10]. It has a weight of 1.8 kg, a cross-axis sensitivity of  $< 1\%$ , and is deployed via a hold down and release mechanism through a Frangibolt assembly. More information about the ILSA Scientific payload is in the table given below [13]:

Parameters	Specifications
Resolution (nano -g/Hz <sup>1/2</sup> )	100
Bandwidth (Hz)	40
Operating temperature (°C)	-20 to +45
Dimensions (mm)	170 × 170 × 72
Power consumption (W)	<4

The graphs shown below show the scientific results obtained by ILSA. It has recorded the vibrations occurring due to the movements of Pragyan and other payloads [15].

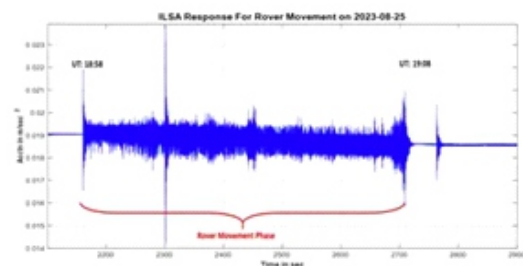
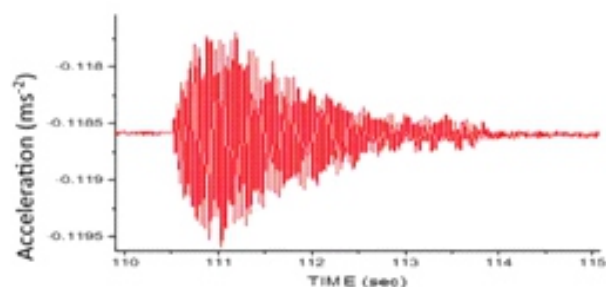


Fig. 8: ILSA Response for Rover Movement Source: ISRO (2023)



**fig. 9: Acceleration measured over a period of time by**

**ILSA**

**Source: ISRO (2023)**

## CONCLUSION

All the scientific payloads of the Chandrayaan-3 mission onboard the lander module (Vikram Lander and Pragyan Rover) have collected the scientific readings (RAMBHA-LP, ILSA, ChaSTE, APXS, and LIBS), and the lander and rover are now in sleep mode. Their awakening is expected to happen on September 22, 2023. Efforts to establish communication with the lander and rover are underway.[16].

## REFERENCES

1. Chandrayaan-3 Details, ISRO, 2023, [www.isro.gov.in/Chandrayaan3\\_Details.html](http://www.isro.gov.in/Chandrayaan3_Details.html).
2. LVM3-M4/CHANDRAYAAN-3 MOON MISSION, 2023, [https://www.isro.gov.in/media\\_isro/pdf/Missions/LVM3/LVM3\\_M4\\_Chandrayaan3\\_brochure.pdf](https://www.isro.gov.in/media_isro/pdf/Missions/LVM3/LVM3_M4_Chandrayaan3_brochure.pdf). Accessed 10 Sept. 2023.
3. Laxmiprasad, A. S., et al. "Laser Induced Breakdown Spectroscopy on Chandrayaan-2 Rover: a miniaturized mid-UV to visible active spectrometer for lunar surface chemistry studies." *Current Science* 118.4 (2020).
4. Libs Confirms the Presence of Sulphur (s) on the Lunar Surface through Unambiguous in-Situ Measurements, ISRO, 2023, [www.isro.gov.in/LIBSResults.html](http://www.isro.gov.in/LIBSResults.html).
5. Sundararajan, Venkatesan. "Overview and technical architecture of India's Chandrayaan-2 mission to the Moon." 2018 AIAA aerospace sciences meeting. 2018.
6. Shanmugam, M., et al. "Alpha particle X-ray spectrometer (APXS) on-board Chandrayaan-2 rover." *Advances in Space Research* 54.10 (2014): 1974-1984.
7. APXS On-Board CH-3 Rover Detects the Presence of Minor Elements, ISRO, 2023, [www.isro.gov.in/APXS.html](http://www.isro.gov.in/APXS.html).
8. The First Observations from the Chaste Payload Onboard Vikram Lander, ISRO, 2023, [www.isro.gov.in/Ch3\\_first\\_observation\\_ChaSTE\\_Vikram\\_Lander.html](http://www.isro.gov.in/Ch3_first_observation_ChaSTE_Vikram_Lander.html).
9. "PRL NEWS – THE SPECTRUM." PRL News - The Spectrum, Sept. 2019, <https://www.prl.res.in/prl-eng/sites/default/files/documents/newsletter/newsletter-september-2019.pdf>. Accessed Aug. 2023.
10. Kosambe, S. (2019). Chandrayaan-2: India's Second Lunar Exploration Mission. *Journal of Aircraft and Spacecraft Technology*, 3 (1), 221-236. <https://doi.org/10.3844/jastsp.2019.221.236>
11. Manju, G., et al. "Lunar near surface plasma environment from Chandrayaan-2 Lander platform: RAMBHA-LP payload." *CURRENT SCIENCE* 118.3 (2020): 383.
12. Rambha-LP on-Board Chandrayaan-3 Measures near-Surface Plasma Content, ISRO, Aug. 2023, [www.isro.gov.in/Ch3\\_Rambha-LP\\_near-surface\\_Plasma.html](http://www.isro.gov.in/Ch3_Rambha-LP_near-surface_Plasma.html).
13. John, J., et al. "Instrument for Lunar Seismic Activity Studies on Chandrayaan-2 Lander." *CURRENT SCIENCE* 118.3 (2020): 376.
14. Chandrayaan2 Complete Project Payloads, ISRO, [www.isro.gov.in/chandrayaan2-payloads.html#:~:text=ILSA%20is%20a%20triple%20axis,seismicity%20around%20the%20landing%20site](http://www.isro.gov.in/chandrayaan2-payloads.html#:~:text=ILSA%20is%20a%20triple%20axis,seismicity%20around%20the%20landing%20site). Accessed Aug. 2023.
15. Ilsa Listens to the Movements around the Landing Site, ISRO,

Aug. 2023, [www.isro.gov.in/Ch3\\_ILSA\\_Listens\\_Landing\\_Site.html](http://www.isro.gov.in/Ch3_ILSA_Listens_Landing_Site.html).

16. Chandrayaan-3, ISRO, 2023, [www.isro.gov.in/Chandrayaan3.html](http://www.isro.gov.in/Chandrayaan3.html).